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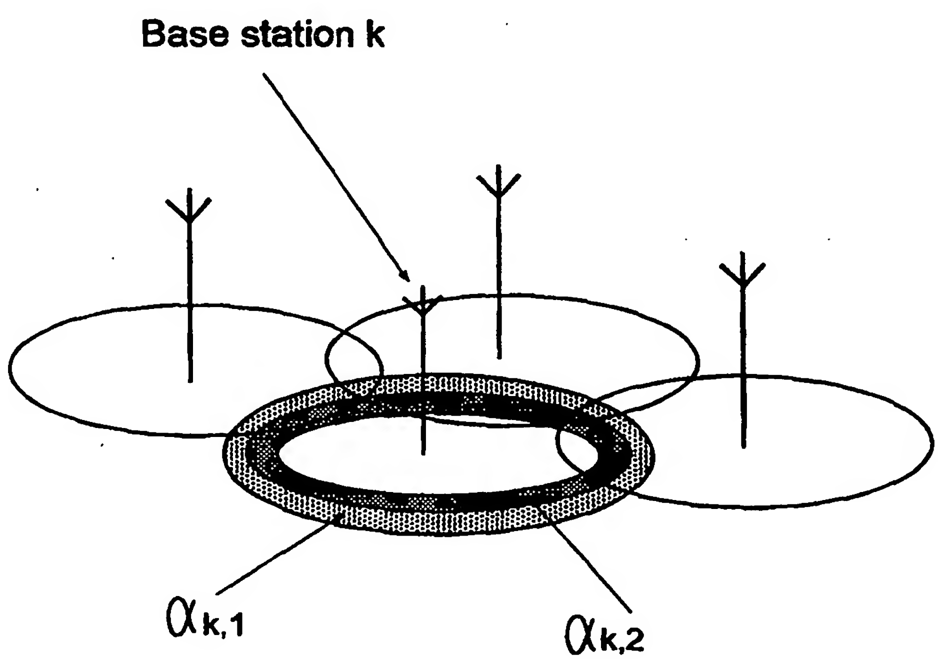
(54) Title: METHOD TO REALLOCATE THE TRAFFIC LOAD IN A CELLULAR MOBILE TELEPHONE SYSTEM

(57) Abstract

Procedure at cellular mobile telephone system which makes possible for an operator to re-allocate the traffic load from one cell to another at packet switched connections in said system, and reroute mobiles which have GPRS-functionality, to cells which are less loaded. The throughput of data in GPRS is increased by letting the connections utilise several time-slots within the same time-frame. A netowrk controlled "cell re-selection"-algorithm orders the mobile to make a "cell re-selection" to one by the network specified cell, at which the algorithm can be used both at set-up of the data calls and during the session in progress.



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METHOD TO REALLOCATE THE TRAFFIC LOAD IN A CELLULAR MOBILE TELEPHONE SYSTEM

TECHNICAL FIELD

Procedure at a cellular mobile telephone system which makes possible for an operator to reallocate the traffic load, from one cell to another, at packet switched connections in said system, and reroute mobiles, which have GPRS-functionality, to cells which are less loaded.

PRIOR ART

General Packet Radio Service (GPRS) is a new service for GSM which makes possible packet switched services. GPRS is a very cost efficient method in the sense that a GPRS mobile utilises the radio channel only when it shall transmit or receive data. GPRS uses to a large extent the same radio network infrastructure (BSS) as GSM and HSCSD. Circuit and packet switched services will therefore to some extent share the same radio resource, which may result in great problems. "Burst-based" data sources which during short periods require high data rates (for instance WWW, file transfer) will call for high demands on the system. Previous investigations have shown that a small number of data users can cause a very high congestion for speech users in a system where speech and data users coexist.

TECHNICAL PROBLEM

An aim of the present invention therefore is to effect a procedure which gives a high throughput of data in the cellular network. The previously known technology of cell re-selection has focussed on speech traffic and only considered the propagation conditions in the network. By the introduction of GPRS more and more situations will occur where different users need different quantities of resources and then it must also be considered what the resource situation in the network looks like. The present

invention with belonging algorithm does just this (in combination with the propagation conditions), and the invention results in that the data rate for GPRS-mobiles can increase as a consequence of a better channel utilisation (truncing loss will decrease).

A trivial method to increase the throughput of data in GPRS is to make the connections (base station - mobile pair) use several time slots within a frame. This is only possibly to a certain level, namely until all time slots are occupied in a base station. Even when this situation arises in the network, it will be possible to increase the total transmission capacity of the system.

The networks of today are designed for "worst-case" situations where, for instance, the frequency allocation must be based on the quality demand of a smallest C/I-value of 9 dB at the cell edge. Further, the number of frequency bands (where each frequency band corresponds to eight time slots) which are allocated to the different base stations must consider the worst case (the traffic peaks) of the load of the system). This results in a less efficient utilisation of spectrum during "non-busy"-periods.

TECHNICAL SOLUTION

The technical solution is described in what is specified in patent claim 1.

ADVANTAGES

By the present invention it will be easier to reroute mobiles to effect a higher security at the transmission, and a higher transmission capacity in the network. Further, the procedure is so general that it can be applied to other cellular packet-oriented systems which have similar requirements as GPRS (for instance UMTS). It should be observed that cell re-selection is a functionality which

the network (i.e. indirectly the operator) decides whether it shall take place.

Another advantage which the invention provides is that the throughput of data in the system is not obtained as a consequence of an impaired communication to users who already have their service running.

DESCRIPTION OF FIGURES

Figure 1 shows a schematic figure which describes the area around a base station where candidates are tried to be found for cell re-selection.

DETAILED DESCRIPTION

In Figure 1 a picture shows how a part of the algorithm which is an integral part of the procedure works, and describes the area around a base station where one tries to find candidates for cell re-selection. One first investigates the area which is defined by the parameter $a_{k,1}$ (light shaded area). If there are no mobiles, one may search further into the cell specified by the parameter $a_{k,2}$ (dark shaded area) etc. This is described in detail later in the text.

The traffic in a cellular mobile telephone system is such that the cells utilise only a part of their total capacity. When the traffic varies, both in time and room, the load between different base stations will fluctuate. It may be that a base station has all its time slots and frequencies allocated to mobile users in its cell, whereas adjacent base stations to this cell are less loaded. Then it is possible to utilise the free capacity in the adjacent base stations to increase the total throughput of data in the system by connecting some mobiles in the heavily loaded base station to these.

According to the specification for GPRS (GSM 03.64 Version 2.02 April 1997), it is the mobile that decides when it is time to make a "cell re-selection", i.e. change of cell by connecting to another base station. The network, however, has means of giving order the mobile to make a "cell re-selection" to one by the network specified cell.

The invention is based on the use of this network controlled "cell re-selection" to reroute mobiles to cells which are less loaded. The invention utilises already existing measurement methods in the mobiles to find out the propagation conditions in the surrounding cells (base stations).

The algorithm which is utilised is based on a classification of the mobiles based on their "distances" from their respective base station. By "distance" here is referred to the value of the attenuation in the radio links to the different base stations. If a mobile has a high attenuation to its present base station (cell), and has a comparatively small attenuation to adjacent cells, this mobile will be a suitable candidate to be selected for cell re-selection.

In the following is presented a detailed description of the algorithm which we utilise, and after that the different steps in the algorithm are explained. When we in the definition of the algorithm talk about mobiles, we refer to mobiles which have GPRS-functionality (can also be in combination with GSM and/or HSCSD).

The algorithm can be used both at establishing of sessions (data calls) and when sessions are in progress. The algorithm can be used in situations where when one or more mobiles in the network want to use more channels than are available in the base station. The algorithm makes use of

thresholds to identify areas around the base stations where candidates for cell re-selection shall be found out. Let the total number of base stations in the network be N. One starts by examining mobiles far away from their respective base stations. The first area for base station j is specified (as below) by a parameter $\alpha_{j,1}$. If the algorithm has not found a mobile in this first area, areas closer and closer to the base station will be examined. This procedure is performed step by step for all base stations. The areas are specified by the parameters $\alpha_{j,m}$, where the parameters fulfils the following relation $\alpha_{j,1} > \alpha_{j,2} > \alpha_{j,3} \ldots\ldots\ldots > \alpha_{j,Kj}$ (j=1,...,N). The number of parameters for respective base station (Kj, j=1,.......,N) and the individual values of the parameters are defined by the operator.

1) The algorithm goes through a loop (step 2-8 below) and makes during the first turn use of the parameters $\alpha_{j,1}$, (j=1,...,N), during the second turn of the parameters $\alpha_{j,2}$, etc.

2) Each mobile measures the signal strength to the neighbouring base stations and the own cell. This can in our algorithm be implemented in different ways. Either one can use RXLEV which the mobile reports to the base station on a regular basis, or one can use a function of this, for instance average RXLEV during a certain defined time interval. As an alternative one can use the C1-criterion according to the GSM-specification (4). Also other measured values based on signal strength can be used. Let $G_{i,j}$ be the measured signal strength value (obtained according to some method) between the base station j and mobile i. For each mobile we now form the difference D_{ij}, between the measured value towards the base station the mobile at present is connected to (serving cell, say that it has index k) G_{ik}, and the adjacent base stations according to the channel list for the adjacent channels.

Consequently we will have:

$$D_{ij} = G_{ij} - G_{ik} \qquad j \neq k \ (\mathrm{dB})$$

for all j which belongs to the channel list for adjacent channels for base station k. This, consequently, is the difference in propagation conditions for mobile *i*.
3) All mobiles which have at least one adjacent base station (say with index *k*) with D_{ij} larger than $\alpha_{k,1}$ constitute candidates for cell re-selection and are part of the number of candidates S. The relation $D_{ij} > \alpha_{k,1}$ will describe an area between the base stations (which in reality is highly irregular) where the algorithm will search for mobiles which are suitable for cell re-selection. An illustration of this is in Figure 1. It is a very schematic figure which describes the "area" around a base station where one tries to find candidates for cell re-selection. First that area is inspected which is defined by the parameter $\alpha_{k,1}$ (light grey area). If there are no mobiles there, one may examine further into the cell specified by the parameter $\alpha_{k,2}$ (dark grey area), etc.

4) For each mobile of the number S, one inspects for each base station, which together with the mobile fulfils the condition $D_{ij} > \alpha_{k,1}$ how many channels x the mobile can have allocated to itself (the maximum number is the number that the mobile wishes) in the potentially new base station. In addition one inspects how many channels y, that can be allocated to other mobiles in the base station to which the mobile in question for the time being is connected (serving cell), given that the mobile makes a cell re-selection to the candidate base station which is regarded. These two are summed up (x+y) and one will have the total number of channels which can be allocated in the network, given that the mobile is connected towards the new base station, i.e. we study the increase of the total data throughput. This is

made for all mobiles in the number of candidates S. These constitute the subset S1. With each mobile in the subset S1 is associated the base station which together with the mobile gives maximal increase of throughput.

5) If there in step 4 would be mobiles which have several candidate base stations which give maximal increase of throughput, one selects for respective mobile the candidate base station which has the highest D_{ij}, i.e. the one with the strongest reception.

6) If there are more than one mobile in the number of S1 after step 5, it is a question of finding a final mobile from the number S1. This is made in the following way:

Power control is not used:
The mobile of the number S1 which has the smallest value G_{ik} is selected to the present cell (serving cell).

Power control is used:
The mobile of the number S1 which has the smallest value of ($P_{j,new}$ - D_{ij}) is selected to the candidate base station which has been obtained in step 5. $P_{j,new}$ is the receiver power which the base station j orders the mobiles (which are connected towards base station j) to adjust to.

7) The network orders the selected mobile to make cell re-selection to the appointed base station. Then the network checks that other radio connections are no too much interfered with.

8) If there would be no mobiles which do not fulfil the condition $D_{ij} > \alpha_{k,1}$ towards any base station, there are no candidates in the area for cell re-selection. This implies that the mobiles in the heavily loaded cells are closer to

their base stations than the cell re-selection thresholds $\alpha_{j,1}$ (j=1,...,N) specifies. Then one may try the parameters $\alpha_{j,2}$ (j=1,...,N) and start again from step 2, i.e. one moves gradually closer and closer to the base stations and examines possible candidates.

9) If the cell which the mobile actually preferably would be connected to again will get vacant time slots, then the mobile which has been ordered to make a cell re-selection again can be connected to this.

The algorithm is specified to have one mobile at a time selected for cell re-selection. Of course it is possible to speed up the procedure by making multiple selections of mobiles (several are selected at the same time). As a suggestion the calculations as above then are made parallel for a plurality (or the number which one wants to take away) mobiles and lists the mobiles in order according to step 2-8.

An explanation of the different steps in the algorithm is given in the following.

1) No explanation necessary.

2) Explained together with step 3 below.

3) The idea is, as has been mentioned, to select the mobiles which, from a propagation point of view are far from the present base station. Note that we will not make a cell re-selection if there are no mobile that fulfils the condition in the last round (i.e. for the parameters $\alpha_{j,Kj}$) even if the system would be "filled up". This is due to the fact that if such a situation should occur, the mobiles are too close to the present base station (serving cell), and to connect them to a base station too far away requires

very high transmission power, which the mobiles may not be able to effect. The number of parameters Kj (j=1,...,N) for respective base station (i.e. the largest area which is regarded for cell re-selection) will be decided by a trade-off between capacity demands and quality demands in the network.

4) This selection is made in order to get as high a data throughput as possible. Note that the algorithm is specified to select only one mobile at a time. If one has a situation where a plurality of mobiles need to make cell re-selection, the cell re-selection for the mobiles will be made in sequence (one at a time). One can of course examine all combinations of mobiles in the network which gives maximal increase of throughput. This actually is an optimal strategy. The problem is that the complexity of such an algorithm will increase exponentially by the number of mobiles which need to make cell re-selection. For practical realisations we suggest that a sup-optimal sequential strategy is used. In the cases when one only needs to make cell re-selection for one mobile, the sequential method of course is optimal.

5) If a mobile has a plurality of base stations to select from (with the same increase of throughput), one selects the one for which the wave propagation conditions are best.

6) If there are a plurality of mobiles which constitute candidates in step 5, one selects strategy depending on if one has power control switched on or not. In the case without power control, one selects the mobile which has the worst propagation conditions to the present base station (serving cell), and which consequently will interfere least when it has been switched over to the new base station. In the case when one has power control, one selects the mobile which gives least interference power in serving cell when

one has switched over the mobile to the new base station. We will explain the latter case in detail (assume the cell re-election mobile has index *i*).

Received power in the new base station (say with index *j*) is adjusted according to continuously received power control as:

$P_{j,new}$ = constant = $G_{ij}+P_i$ (dB), where P_i is the mobile's transmitting power.

=> $P_i = P_{j,new} - G_{ij}$

=> Received interfering power in the old base station:

$P_{k,old} = G_{ik}+P_i = G_{ik}+P_{j,new} - G_{ij} = P_{j,new}-D_{ij}$

Consequently, to minimise received interfering power in serving cell after cell re-selection is the same as to select the mobile which will have the smallest value of $P_{j,new}-D_{ij}$.

7) We deal with point 7 below.

8) This point is self-explaining.

9) The mobile is connected to a cell to which it has not best propagation conditions (but which may be sufficiently good). If time slots become vacant in the for the mobile "best" base station, one should switch back the mobile to this, to reduce the need of transmitted power from the mobile.

Interference towards other links

The algorithm is aggressive in so far as it tries to increase the throughput of data in the system towards a

potential increase of the interference in the network. Problems of course can arise if too much interference is created in other connections so that their communications quality falls below an acceptable level. Then the network has to do something to solve this problem. We will discuss this for two frequent cases:

Fixed frequency allocation:
Fixed frequency allocation exists in the GSM-systems of today. This means that the base stations are permanently allocated a number of frequency bands which can be used for communication with the mobiles in the belonging cell. There also is possibility to hop on these frequencies (base band hop). The allocation of frequencies is planned so that adjacent cells (base stations) do not use the same frequencies, and that two cells which have been allocated the same frequency are sufficiently far from each other. This results in that, in the case with fixed frequency allocation, the problematic situation above will not occur. A mobile which is switched over to a base station according to the algorithm does not interfere with any other connection to any great extent (the system is so designed) but may risk that the own connection will have too poor communication quality. Consequently it is in principle only the connection which makes the cell re-selection that can be afflicted.

Synthesis hopping with small repetition distances:
In a near future synthesis hopping can be used in the system and then it will be of interest to hop over the whole bandwidth which an operator has been allocated. There of course are implementation aspects which limits to what extent this can be done, but the idea itself is that (in addition to frequency diversity) effect interference diversity in the system and at the same time reduce the size of the cluster. This may result in a considerably

better utilisation of the expensive radio resource. The consequences for the algorithm above is that one cannot guarantee that users in two adjacent cells do not use the same frequency during all time slots, i.e. there may in this case arise situations when a cell re-selection connection can interfere with other radio connections in the network. Regarding frequency hopping, and especially synthesis hopping, there are problems of identifying which transmitter/receiver-pair that are interfering in the network. This is a general problem and is not specific to our algorithm. We suggest that the problem (and point 7 in the algorithm above) in this case is solved in the following way:

Because we are studying a GPRS-system which transports principally non-real time services, we have a re-transmission protocol which requests re-transmissions if the packets are received with too many errors (the communication quality is too poor). If the now switched over mobile would cause problems, this will be observed by that the number of re-transmissions for mobiles in adjacent cells and mobiles in the old cell is increased. If there would occur a heavily increased number of re-transmissions, this is a sure symptom of that the performed cell re-selection would not have taken place. One then can chose to regard the cell re-selection action as a failed attempt and order the cell where the transferred mobile is to stop the transmission. Or one can chose to let the transmission go on at the price of a deteriorated quality for the specific mobiles which are negatively influenced by the interference. The latter usually is called "graceful degradation".

The invention is of course not limited to the above specified embodiment, but may be subject to modifications within the frame of the idea of the invention illustrated in the following patent claims.

PATENT CLAIMS

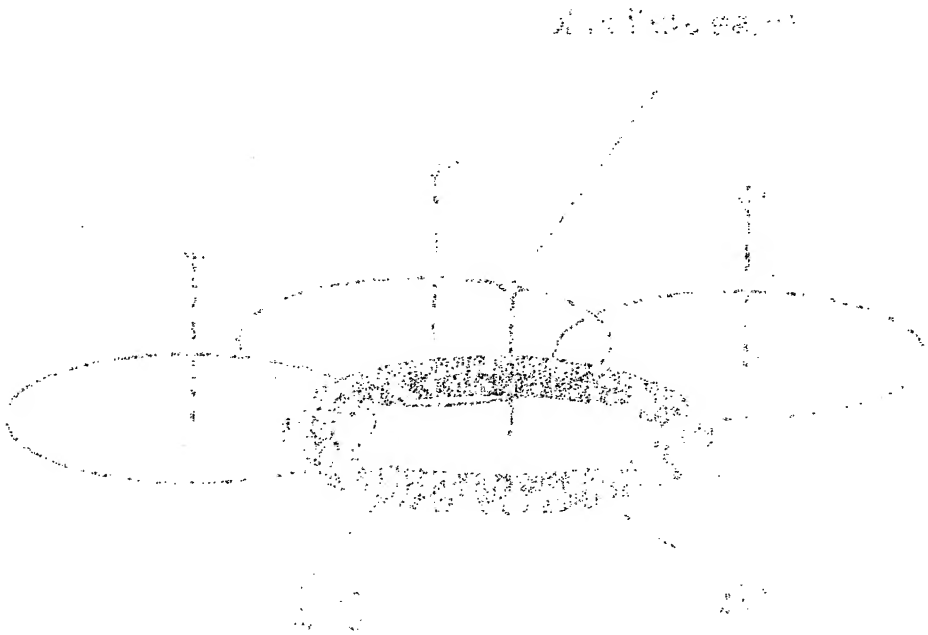
1. Procedure at a cellular mobile telephone system which makes possible for an operator to re-allocate the traffic load from one cell to another, at packet switched connections in said system and reroute mobiles which have GPRS-functionality, to cells which are less loaded, c h a r a c t e r i s e d in that the throughput of data in GPRS is increased by letting the connections utilise several time slots within the same time frame, at which a network controlled "cell re-selection"-algorithm orders the mobile to make a "cell re-selection" to one by the network specified cell, at which the algorithm can be used both at set-up of the data calls, and during the session in progress.

2. Procedure according to patent claim 1, c h a r a c t e r i s e d in that the algorithm utilises threshold values to identify areas around base stations where candidates for cell changes shall be found out.

3. Procedure according to patent claim 1, c h a r a c t e r i s e d in that the algorithm utilises existing measuring methods in the mobiles to find out the propagation conditions to the adjacent cells (base stations).

4. Procedure according to patent claim 1, c h a r a c t e r i s e d in that the algorithm is based on a classification of the mobiles is based on the size of the attenuation in the radio links to the different base stations, at which a mobile which has a high attenuation to its present base station (cell) and has a comparatively small attenuation towards adjacent cells, is selected for cell re-selection.

5. Procedure according to patent claim 4, c h a r a c t e r i s e d in that the algorithm can be used to select one mobile at a time for cell re-selection, or to select a plurality of mobiles for cell re-selection.



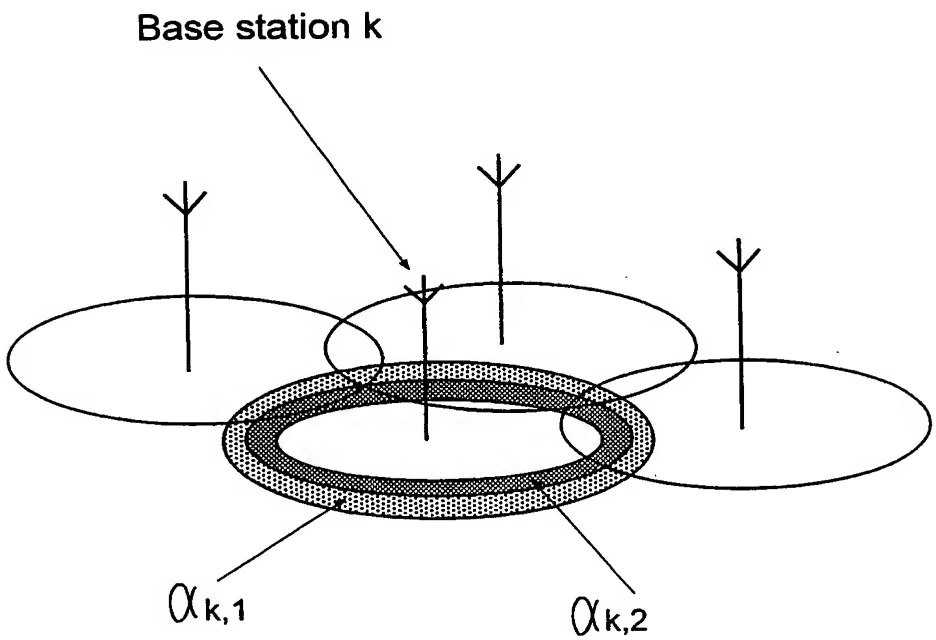


Figure 1

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 99/00476

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: H04B 7/26, H04L 12/56, H04Q 7/38

According to International Patent Classification (IPC) or to both national classification and IPC

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Minimum documentation searched (classification system followed by classification symbols)

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Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

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Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

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[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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Information on patent family members

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